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1. Original utility patent application for the invention by Daniel M. Joffe, et al of a "Method and Apparatus for Reducing Flux Imbalance Signal Distortion in a Data Communications System" which includes:
   a. specification;
   b. 7 pages of drawings;
2. Original filing fee in the amount of $760.00.
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APPLICATION FOR

UNITED STATES LETTERS PATENT

Be it known that we, Daniel M. Joffe, a citizen of United States, residing at 2732 Tammerack Lane, Huntsville, Alabama 35763; Richard L. Goodson, a citizen of the United States, residing at 811 Jacqueline Drive, Huntsville, Alabama 35802; and Curtis W. Dodd, a citizen of the United States, residing at 2803 Bentley Street, Huntsville, Alabama 35801, have invented a new and useful "Method and Apparatus for Reducing Flux Imbalance Signal Distortion in a Data Communications System."

BACKGROUND OF THE INVENTION

The present invention relates in general to communications systems, and is more particularly directed to a simplex power feeding arrangement for furnishing power from a central location to a remote location in a high-speed data communications system.

This invention is directed towards the reduction of distortion in the signal transfer from the central location to the remote location that may be caused by a flux imbalance in the coupling transformers. This flux imbalance can cause a reduction of the data transmission rates in high-speed communication systems.

Simplex power feeding arrangements, by their nature, cause very little additional net DC flux density in a transformer. Typically, only an imbalance in the ampere-turns product of each half of the line-side transformer windings causes an

undesirable additional DC flux density sometimes referred to as a flux imbalance. However, as transformers become smaller and data signal constellations have an increasing number of points, even a slight flux imbalance may cause significant and undesirable distortion in transmission signals. This distortion produces the most negative effect in echo-cancelled systems, where the local transmitter signal must be precisely cancelled to allow error-free reception of the remote signal. Distortion-free coupling of the local signal makes cancellation a relatively simple linear process, as compared to a complex non-linear process that might otherwise be required. Hence, there is a need for a way to counteract the imbalance in the transformer and thereby remove or reduce the distortion or non-linearity.

The problem of distortion caused by the flux imbalance may be solved if there is a way to counteract the magnetomotive force that produces the imbalance. Such a solution could achieve near maximum linearity while maintaining minimum size components.

In order to understand the benefits of a simplex powering apparatus and the flux imbalance problem it is useful to review a data communication system **100** shown in Fig. 1 with a simplex powering arrangement. The data communication system **100** utilizes a line powering supply **105** that may be located at a central location **96** of the communication system **100**. This line powering supply **105** transfers power via communication lines **108, 109** to a power supply **106** at a remote location **98**. The communication lines **108, 109** are typically twisted pair lines. The power supply **106** at the remote location **98** provides power to remote

data communications equipment, such as transceivers **110** and **112**, or other data communications devices.

Although variations in the electrical characteristics of each coupling transformer **121, 122, 123, 124** or lines **108, 109** connecting the central location **96** to the remote location **98** are small, slight variations may cause a net DC flux density. This net DC flux density produces distortion in data communication system **100** having small transformers **121, 122, 123, 124**. Modulation methods with a large number of constellation points may be affected to a greater extent by the distortion caused by the net DC flux density imbalance. In echo-cancelled systems with a large number of constellation points, the need for linearity is greatest. A highly linear system affords a relatively easy linear cancellation of the near-end signal, as opposed to a relatively difficult non-linear cancellation. Although a larger transformer may reduce the distortion problem, continual market pressure exists to make electronic communication devices smaller while increasing the data rate and therefore the need for constellations with a large number of points. Hence, there is a need for a method of removing the flux imbalance and allowing for the use of smaller sized magnetic devices such as transformers while maintaining or improving performance caused by the distortion due to flux imbalance.

SUMMARY OF THE INVENTION

One object of the present invention is to reduce the DC flux density in the magnetics of a transformer in a simplex power feeding arrangement such that the

net DC flux density approaches zero without adding significant complexity or size to coupling transformers of transceivers used in a communication system.

A further object is to provide a reduction in the DC flux imbalance that is adaptable to variations in transformer and line characteristics.

Yet another object of the present invention is to minimize the flux imbalance that may be generated as a consequence of non-idealities within the electrical circuits of the transmitter, such as by an offset voltage in an output amplifier.

An apparatus in a transceiver meeting the above and other objects is comprised of a means for measuring signal quality combined with a DC current injection means. The signal quality measuring means is comprised of a sampler and signal quality calculator. In a first embodiment, the sampler monitors the output of an echo canceller during simplex transmission and the quality calculator determines the average magnitude of the output of the echo canceller and then directs the DC injection means to add a flux cancellation signal to the transmit signal in accordance with a flux cancellation algorithm. The flux cancellation signal and transmit signal are digital values and are converted to an analog signal, via a D/A converter, before going to an output amplifier. The flux canceller algorithm increases or decreases the flux canceller signal to reduce the value of the average magnitude of the output of the echo canceller.

The apparatus may be modified to provide for cancellation of the imbalance during a full duplex data mode by using an error signal from a linear equalizer as an input to the distortion measuring means.

A method for minimizing the distortion due to flux imbalance comprises the steps of: measuring the quality of the signal; injecting a DC current in an equipment side winding of a coupling transformer; measuring the quality again; increasing the injected DC current if quality has improved else decreasing the injected DC current; and repeating the above steps thereby reducing the distortion caused by flux imbalance.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic drawing of conventional simplex power arrangement used in a high speed communications system.

Fig. 2 is a schematic diagram of a summing amplifier for furnishing a flux cancellation voltage in accordance with the present invention.

Fig. 3 is a schematic and block diagram of a first embodiment of an apparatus for flux cancellation in accordance with the present invention.

Fig. 4 is a flow chart illustrating a first flux cancellation algorithm in accordance with the present invention.

Fig. 5 is a schematic and block diagram of a second embodiment of an apparatus for flux cancellation in accordance with the present invention.

Fig. 6 is a flow chart illustrating a second flux cancellation algorithm in accordance with the present invention.

Fig. 7 is a flow chart illustrating a method for flux cancellation in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to a simplex power feeding arrangement shown in the high speed communication system **100** of Fig. 1, the signal distortion problem associated with a net DC flux density can be understood. Line power and communication signals are often transmitted over two pairs of wires **108, 109** in the communication system **100** with a simplex powering arrangement. A central transceiver **101** and central transceiver **102** at a central location are coupled to a remote transceiver **110** and remote transceiver **112** over the communication lines **108, 109**. A line powering supply **105** at the central location furnishes DC current to a remote power supply **106** at the remote location. The remote power supply **106** furnishes power to the remote transceiver **110** and remote transceiver **112**. The simplex powering arrangement has the advantage that the DC current furnished by the line powering supply **105** produces nearly equal and opposite flux densities in a first transformer **121** as illustrated in Fig. 1. Current **I1** from the line powering supply **105** splits into two components, **I2** and **I3**. If **I2** and **I3** are exactly equal and the number of turns in the **I2** half or top side of the first transformer **121** is the same as the number of turns in the **I3** half or bottom side of first transformer **121**, then no net DC flux density is produced in the first transformer **121**. As shown by the dots **107** on first transformer **121**, **I2** flows out of a non-dotted end, and **I3** flows out of a dotted end. The dot notation is a standard and well-known convention for showing opposite signs in ampere-turns, or magneto-motive force. To the extent that **I2** and **I3** do not exactly match, or that the number of turns in the first transformer **121**

winding halves (**N2** and **N3** as shown in Fig. 2) are not exactly equal, there will be a net DC flux density. For example, the currents **I2** and **I3** will not match if the resistance of the **I2** path is not equal to the resistance seen by the **I3** path. This net flux density can cause distortion problems for the communication system **100**.

The net flux density, also referred to as an uncancelled flux density, caused by the ampere-turn imbalance can be compensated or essentially removed by generating a compensating flux density in accordance with the present invention. The compensating flux density would be equal and opposite to the DC flux density produced by currents **I2** and **I3**. The end result of the combination of the uncancelled flux density and the compensating flux density in accordance with the present invention is a DC flux density in first transformer **121** much closer to zero. Typically, when the DC flux density is essentially zero then distortion in first transformer **121** is minimized. Fig. 1 also shows that a return path for current **I1** is provided through the third transformer **123**, fourth transformer **124**, second communication line **109**, and second transformer **122**.

Fig. 2 illustrates details of the first transformer **121**, the amplifier **208**, and the connections for other components for providing the compensating flux density. This compensating flux density is used to offset or cancel the uncancelled flux densities due to imbalances in currents **I2**, **I3**, and the windings **N2**, **N3**, and **N4**. By adding a flux canceller signal **202**, which comprises a varying voltage signal, to the summer amplifier **208** there is provided an additional degree of freedom to

assure that the net DC flux in the transformer **121** is zero as expressed by the equation:

$$I2 \cdot N2 - I3 \cdot N3 + I4 \cdot N4 = 0$$

In the ideal case, I2*N2 and I3*N3 are equal and there is no need for a flux canceller signal or the ampere-turns expression I4 * N4 of the equation. The line side transformer windings **N2** and **N3** are on the line side of the transformer **121** and the equipment side winding **N4** is on the transmitter side of the transformer **121**. The currents **I2** and **I3** are typically DC currents but may contain small variations with time as conditions change, such as a change in line characteristics due to temperature change. In the above equation, the flux canceller signal is used to cancel whatever uncancelled flux remains in order to minimize the transformer distortion due to flux imbalance.

Now that a concept for a method and apparatus has been disclosed for minimizing flux density and thereby minimizing distortion, details of a method and a preferred embodiment will be given. Further, an apparatus for measuring distortion and selecting a value for the flux canceller signal is also described.

Fig. 3 is a schematic and block diagram of the transceiver and transformer sections of a typical full-duplex echo cancelled data transmission system **100** (Fig. 1). The transceiver may also be used in a simplex mode, such as during a training mode. The transceiver includes a flux generator circuit formed by the combination of a signal summer **302**, a D/A converter **304**, a filter **306**, and amplifier **206**. A digital transmit signal **301** enters a summer **302**. The summer **302** adds the digital

transmit signal **301** with a flux cancellation signal **303** to form a digital transformer signal **305**. The digital transformer signal **305** is converted by digital to analog converter **304** and analog filter **306** to an analog transformer input signal **307**. The analog transformer input signal **307** is then processed through amplifier **206** to form amplified transformer signal **309**. The amplified transformer signal **309** is then sent to the equipment-side winding **N4** in the transformer **121**. The winding **N4** in the transformer **121** converts the amplified transformer signal **309** into a transmitter signal, which includes a cancellation flux. The cancellation flux offsets the flux imbalance in the transformer to reduce or eliminate the flux imbalance. The use of a transformer winding to create flux is well known in the prior art.

The amplified transformer signal **309** is also sent to a combination echo canceller **308**, which includes an analog echo canceller **310** followed by an analog to digital converter **312** and digital echo canceller **314**. The combination echo canceller **308** is provided to cancel the near-end signal so that only the far-end signal and whatever nonlinear portion of the near-end signal remain. When the data transmission system **100** is operating in the simplex mode, the far-end signal is non-existent or zero. The combination echo canceller **308** is well known and understood by those skilled in the art of telecommunications and thus, no further comments will be given on this aspect of the invention.

Typical echo cancellers **310**, **314** function as linear cancellers. These typical cancellers pass do not cancel non-linear echo components, such as those generated in transformer non-linearities such as flux imbalances. Thus, the flux imbalance

detection signals are not removed from the transformer signal. Therefore, the echo cancellers generate a detected quality signal that includes indications of the flux imbalance in the transformer. These uncancelled signals represent a distortion in the telecommunication system. Accordingly, the echo canceller acts as a distortion measuring circuit.

The output of the digital echo canceller **314** minus any far-end signal represents a canceller error signal **315**. This canceller error signal **315** is a measure of system distortion or quality. A relatively large magnitude for the echo canceller error signal **315** is an indication of poor quality and distortion. The echo canceller error signal **315** may be used in a feedback path to adjust the flux canceller signal **303** and thereby improve signal quality by driving distortion to a minimum.

The improvement of the signal quality may be accomplished by using the canceller error signal **315** of the combination echo canceller **308** as a detected quality signal, and monitoring it with a flux controller **320**. The flux controller **320** uses the detected quality signal to furnish a flux canceller signal **303** to the summer **302**. The flux canceller signal **303** is the source for injecting a flux-canceling DC current into equipment-side winding **N4**. The flux canceller signal **303** is generated in accordance with the programming of the flux controller **320**.

In the simplex mode, the transceiver **100** adjusts the flux canceller signal **303** when the local transmitter is active and the far-end signal is silent. When the far-end signal is silent, the detected quality signal is directly related to the undesired signal. One measure of the undesirable signal is determined by calculating the

average magnitude of the detected quality signal over a group of samples. Those skilled in the art will recognize that alternative measures of the undesirable signal, such as the RMS value of the detected quality signal, could be used without departing from the scope of the present invention. Any method for determining a measure of the undesired signal may be used that is associated with the generation of the correcting flux. Upon determining a magnitude of the undesirable signal, then the flux canceller signal **303** is determined in accordance with an adjustment algorithm **400** as shown in Fig. 4.

Referring now to Fig. 4, a first step **410** is to initialize the flux canceller signal. In the preferred embodiment, this initializing step **410** sets the canceller signal to zero. Next, the undesired signal is measured (step **420)** to provide a baseline value. The process continues by repeatedly changing and monitoring the flux canceller signal (step **425**) to minimize the error signal. This changing and monitoring step **425** may be performed by increasing (step **430**) the flux canceller signal **303** (Fig. 3) to modify the distortion caused by the transformer. The system will then compare (step **440**) the increase-modified canceller error signal against the baseline value. If the increase in the flux canceller signal **303** reduces the undesired signal or canceller error signal **315**, the system will attempt another increase of the flux canceller signal **303** to obtain additional reductions in the error signal **315**. However if the undesired signal becomes larger and the distortion has increased, and the system will decrease (step **450**) the flux canceller signal **303**. The system will then compare (step **450**) the decrease-modified canceller error

against the current baseline value. If a reduction of the undesired signal is obtained, the step **450** of decreasing the flux canceller signal is repeated. This process is repeated until there is no further decrease in the undesired signal. The algorithm **400** then returns to step **430** to attempt additional reductions in the undesired signal. In the flow chart, the increase step **430** moves the flux canceller signal **303** in a positive direction and the decrease step **450** moves the flux canceller signal **303** in a negative direction.

The magnitude of increases and decreases in the flux canceller signal **303** may be varied. Typically, a range of positive and negative values of the flux canceller signal **303** is required to accommodate a range of flux imbalances. The flux canceller signal **303** may be also adjusted during full duplex transmission when the far-end signal is present; however, a different measure of signal quality may be required. In both transmission modes (simplex or full duplex), a quality measure related the amount of undesired signal is required and the flux canceller signal **303** is adjusted in accordance with the detected quality signal to minimize the undesired signal.

The adjustment procedure is also used beneficially to compensate for offset voltages that might be present at the output of the driver amplifier **206** shown in Fig. 3. If such an offset voltage is present, the offset voltage would cause a non-zero DC flux density in the transformer even if the line side currents and turns ratios were perfectly balanced. The system of this invention will detect these errors and generate a corresponding signal correction for the system.

Fig. 5 is a block diagram of a transceiver **500** for full-duplex transfer of data in accordance with the present invention. Both input data **501** and output data **502** are handled by this transceiver **500**. Input data **501** is sent from the central location to the remote location and a signal from the remote location results in output data **502**.

The input data **501** is supplied to the transmitter **510**. The output of transmitter **510** is a digital transmit signal and is combined with the flux canceller signal from flux controller **320** by digital summer **512**. The transceiver **500** then operates in a similar manner to the previously described embodiment for transmitting the signal. The output of the summer summer **512** goes through a D/A converter **304** and a filter **306** to a line driver circuit **513**. On the receiving end, the combination echo canceller **308** provides a signal to an equalizer **514**. Summer **512**, D/A converter **304**, filter **306**, and line driver circuit **513** function together as a flux generator. The equalizer **514** has an equalizer error signal used as the detected quality signal that is equivalent to the canceller error signal minus the output data signal. The arrangement for generating this type of signal is well-known to those skilled the design of data communications transceivers. One technique for providing the detected quality signal is to apply the output of equalizer **514** to a decision device which generates the constellation point closest to the equalizer output. The difference between the equalizer output and the decision device output is the detected quality signal. The detected quality signal is used a measure of quality and is provided as an input to the flux controller **320**. An RMS value or

average magnitude of the detected quality signal over N samples may now used as the measure of quality. The lower the value of the average magnitude, Q_i, the smaller the value of the distortion.

A second algorithm utilizing the reduction in Q_1 in accordance with the present invention is shown in Fig. 6. The flux canceller signal is initialized at step **610** and, in the preferred embodiment, is set to zero. At step **620**, the signal quality is determined and saved as Q_1. The flux canceller signal is then incremented (step **630**) and a new measure of quality is made (step **640**) and saved as Q_2. The two measures, Q_1 and Q_2, are then compared (step **650**) and if the quality is improved then Q_1 is set (step **660**) to be equal to Q_2 and steps **630** through **650** are repeated. If the comparison step **650** shows that quality has not improved, then the flux canceller signal is decremented (step **670**), and a quality measurement (step **680**) is made. The two measures, Q_1 and Q_2, are then compared again (step **685**) and if the quality is improved then the Q_1 is set at step **690** to be equal to Q_2 and steps **670** through **685** are repeated. If no improvement is made, then the program returns to step **630** to begin the correction process again.

Figs. 4 and 6 each describe flux canceller algorithms for generating the flux canceller signal in accordance with the present invention. Those skilled in the art would appreciate that any measure of quality could be used to provide the flux canceller signal. Fig. 7 describes the overall method of the present invention. The flux canceller signal is set (step **710)** to an initial value, typically zero. In step **720** a quality measurement is made and the flux canceller signal is adjusted (step **730**).

The flux canceller signal is then measured and readjusted (step **740**) in response to the changes in quality in accordance to a flux canceller algorithm.

Although there have been described particular embodiments of the present invention of an apparatus and method for reducing flux imbalance distortion in a high speed communications system, it is not intended that such embodiments be construed as limitations upon the scope of the invention except as set forth in the following claims.

CLAIMS

What is claimed is:

1. In a data communications system using a power feeding arrangement with a coupling transformer having an equipment side winding and a line side winding, an apparatus for reducing signal distortion caused by a flux imbalance associated with the transformer comprising:

a. a distortion monitoring circuit having a monitoring input coupled to the equipment side winding of the coupling transformer and operative to generate at an error output an error signal corresponding to measurements of the signal distortion sampled by the monitoring circuit;

b. a flux controller having a control input in electrical communication with the error output of the distortion monitoring circuit and operative to generate at a control output a flux cancellation signal in response to the error signal; and

c. a flux generator having a first generator input in electrical communication with the control output of the flux controller and a generator output in electrical communication with the equipment side winding of the coupling transformer, the flux generator responsive to the flux cancellation signal to generate a cancellation flux to reduce the flux imbalance.

2. The apparatus of Claim 1 wherein the distortion monitoring circuit comprises an echo canceller.

3. The apparatus of Claim 1 wherein the distortion monitoring circuit further comprises an equalizer circuit electrically connected between the echo canceller and the control input.

4. The apparatus of Claim 2 wherein the echo canceller comprises a combination of an analog echo canceller, an analog to digital converter, and a digital echo canceller operatively connected in logical sequence between the equipment side winding of the coupling transformer and the control input of the flux controller.

5. The apparatus of Claim 1 wherein the flux generator comprises a signal summer having a second input connected to a transmit signal.

6. The apparatus of Claim 5 wherein the signal summer is a digital summer and the flux generator further comprises a digital to analog converter connected between the digital summer and an analog filter.

7. The apparatus of Claim 6 wherein the flux generator further comprises a line driver circuit operatively connected between the analog filter and the equipment side winding of the coupling transformer.

8. The apparatus of Claim 7 wherein the line driver circuit comprises an amplifier.

9. The apparatus of Claim 1 wherein the distortion monitoring circuit and flux controller are operative to measure a plurality of samples of the signal distortion and to vary the error signal and flux cancellation signal in response to measured changes in the samples of the distortion signal.

10. A flux imbalance compensator for a data communication system having a transmit signal and a coupling transformer with an associated flux imbalance, the compensator comprising:

a. a signal quality monitor circuit electrically connected to the transformer and operative to detect the flux imbalance associated with the transformer and to generate a detected quality signal;

b. a flux cancellation signal generator electrically connected to the signal quality monitor circuit and operative to receive the detected quality signal and generate a flux cancellation signal in response thereto;

c. a signal summer for generating a transformer signal by combining the input data signal and the flux cancellation signal; and

d. a line driver circuit coupled to the transformer for receiving the transformer signal and generating a cancellation flux to reduce the flux imbalance.

11. The flux imbalance compensator of Claim 10, the line driver circuit comprising an amplifier connected between the signal summer and the flux generator for amplifying the transformer signal.

12. The flux imbalance compensator of Claim 10 further comprising an analog filter operatively connected between the signal summer and the line driver circuit.

13. The flux imbalance compensator of Claim 10, the signal quality monitor including an analog canceller.

14. The flux imbalance compensator of Claim 10 wherein:

a. the transmitter signal comprises a digital transmit signal;

b. the signal summer includes a digital signal summer for receiving and combining a digital cancellation signal and the digital transmit signal to create a combined digital signal, and a digital to analog converter to convert the combined digital signal into the transformer signal;

c. the signal quality monitor includes an analog to digital converter connected to a digital echo canceller and operative to convert the transformer signal from analog to digital format, the digital echo canceller also connected to the digital input data signal, wherein the signal quality monitor monitors the transformer signal and the digital transmit signal to produce the detected quality signal including a digital detected quality signal as an output of the digital echo canceller; and

d. the cancellation signal generator processes the digital detected quality signal to generate the cancellation signal including the digital cancellation signal.

15. A circuit associated with a data transmission system for reducing a flux imbalance associated with a transmit signal sent through a power feeding transformer comprising:

a. an echo canceller for generating a canceller error signal;

b. a flux controller in electrical communication with the echo canceller and operative to monitor the canceller error signal and to generate a responsive flux canceller signal;

c. a signal combiner for summing the transmit signal with the flux canceller signal to form a transformer input signal; and

d. a winding in the transformer for receiving the transformer input signal and generating a flux to reduce the flux imbalance.

16. The circuit of Claim 15 further comprising a signal amplifier electrically connected between the signal combiner and the winding.

17. The circuit of Claim 16 further comprising an analog filter electrically connected between the signal combiner and the signal amplifier.

18. The circuit of Claim 17 further comprising a digital to analog converter electrically connected between the analog filter and the signal combiner.

19. The circuit of Claim 15, the echo canceller including an analog echo canceller.

20. The circuit of Claim 19, the echo canceller further including an analog to digital converter electrically connected to an output of the analog echo canceller and a digital echo canceller electrically connected an output of the analog to digital converter.

21. The circuit Claim 15 wherein the echo canceller includes a digital echo canceller.

22. A device for reducing an unwanted flux in a duplex data transmission system sending a digital transmit signal having a near end signal and a far end signal through a transformer comprising:

a. a digital summer for combining a digital flux cancellation signal with the digital transmit signal to form a digital combination output signal;

b. a digital to analog converter for converting the digital combination output signal into an analog combination output signal;

c. a line driver circuit for powering transmission of the analog combination output signal through the transformer and thereby generating a flux to offset the unwanted flux and receiving a return signal including a flux from the transformer;

d. an echo canceller for canceling the near-end signal so that only the far-end signal remains, the echo canceller including an analog echo canceller connected to a digital echo canceller through an analog to digital converter, the digital echo canceller operative to generate a digital error signal;

e. an equalizer for separating the far end signal from the digital error signal; and

f. a flux controller for receiving the digital error signal and generating the digital flux cancellation signal.

23. A method for reducing distortion associated with a flux imbalance in a coupling transformer used in a power feeding arrangement for a data communication system, the method comprising the steps of:

a. measuring the distortion to obtain an error signal;

b. generating a flux cancellation signal from the error signal;

c. using the flux cancellation signal to generate a compensating flux signal; and

d. applying the compensating flux signal to the transformer to reduce the flux imbalance.

24. A method for offsetting an undesired signal in a data transmission system sending a digital transmit signal through a transformer comprising:

a. setting a flux canceller signal to an initial value;

b. obtaining a first measurement of the undesired signal in the transformer;

c. making a first adjustment of the flux canceller signal from the initial value according to the first measurement of the undesired signal;

d. generating a flux offset signal in response to the first adjustment of the flux canceller signal;

e. combining the flux offset signal with the digital transmit signal;

f. obtaining a second measurement of the undesired signal and comparing the second measurement with the first measurement; and

g. making a second adjustment of the flux canceller signal in accordance with the comparison between the first and second measurements of the undesired signal.

25. A method for multiple signal adjustment to offset an undesired signal in a data transmission system sending a transmit signal through a power feeding transformer comprising:

a. initializing a flux canceller signal value;

b. measuring a signal quality to determine properties of the undesired signal;

c. modifying the flux canceller signal value in accordance with the measurement of the signal quality;

d. generating an offset flux in accordance with modification of the flux canceller signal value;

e. combining the offset flux with the transmit signal; and

f. repeating the steps of measuring, modifying, generating, and combining until the measured signal quality reaches a pre-determined threshold.

26. In a simplex power arrangement of a data communications system having a transceiver with a transmit signal and further having an echo canceller providing an error signal responsive to nonlinearities caused by flux imbalance in a coupling transformer, an apparatus comprising:

a. a flux controller for generating a flux canceller signal in response to the error signal and in accordance with a flux cancellation algorithm;

b. a signal summer for combining the transmit signal and the flux canceller signal; and

c. an amplifier coupled to the summer, the amplifier providing an output signal to a winding on a transceiver side of the transformer.

27. In a simplex power arrangement of a data communications system having a transceiver generating a transmit signal and further having an echo canceller having an error signal responsive to flux imbalances associated with a coupling transformer in the system, a method for canceling signal nonlinearities caused by the flux imbalances comprising the steps of:

a. measuring the error signal;

b. adjusting a flux canceller signal to a new value based on the measurement of the error signal;

c. re-measuring the error signal; and

d. readjusting the flux canceller signal in accordance with a flux cancellation algorithm.

ABSTRACT OF THE DISCLOSURE

A method and apparatus for reducing signal distortion in a high speed data communications system caused by a flux imbalance in a system coupling transformer. The signal distortion is monitored by a combination echo canceller circuit connected to the equipment side winding of the transformer, thereby generating an error signal. Changes in the error signal are used by a flux controller to provide a flux cancellation signal. The flux cancellation signal is added with the data signal to generate an offsetting flux signal to the transformer.

FIG. 1

Data Communication System with Simplex Powering Arrangement

100

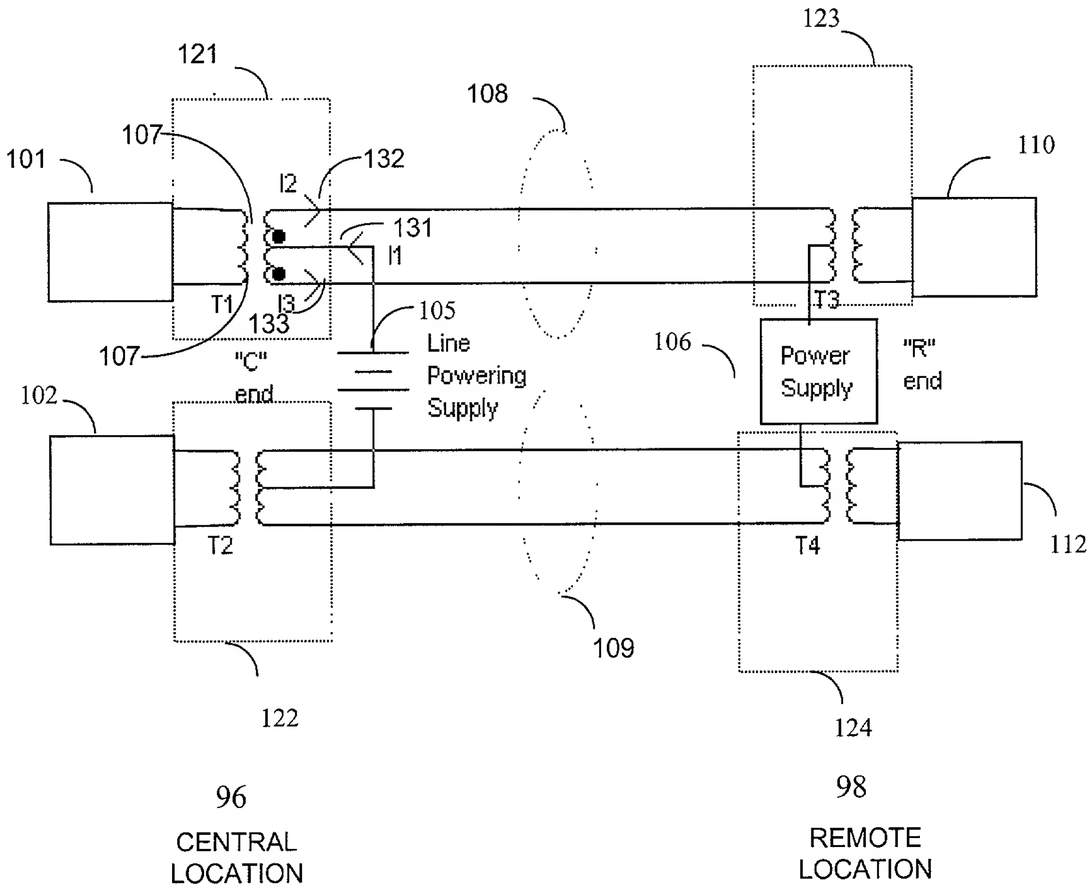


FIG. 2

Principle of operation
of flux canceller

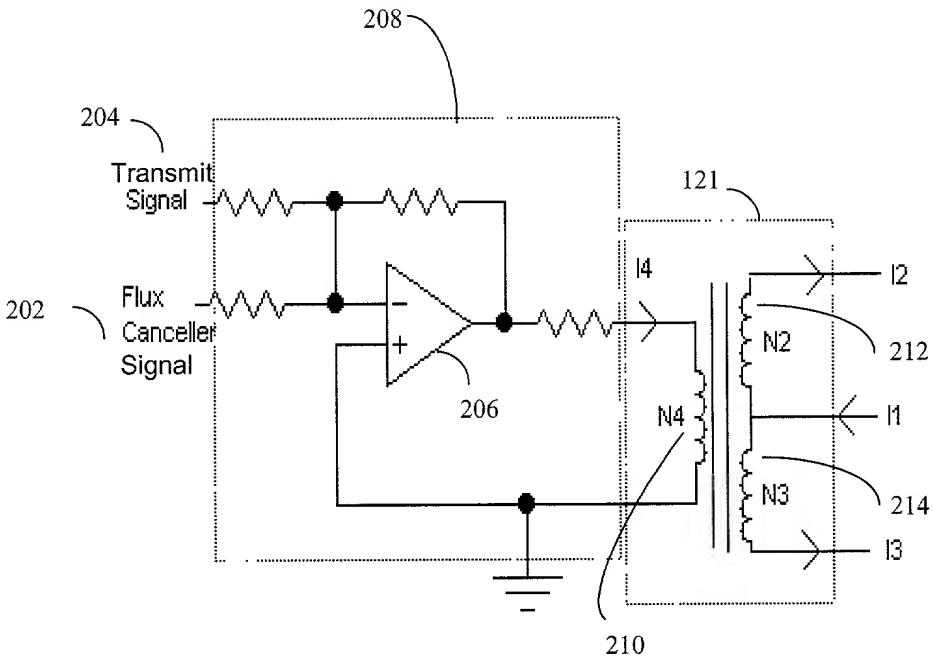


FIG. 3

Line interface arrangement

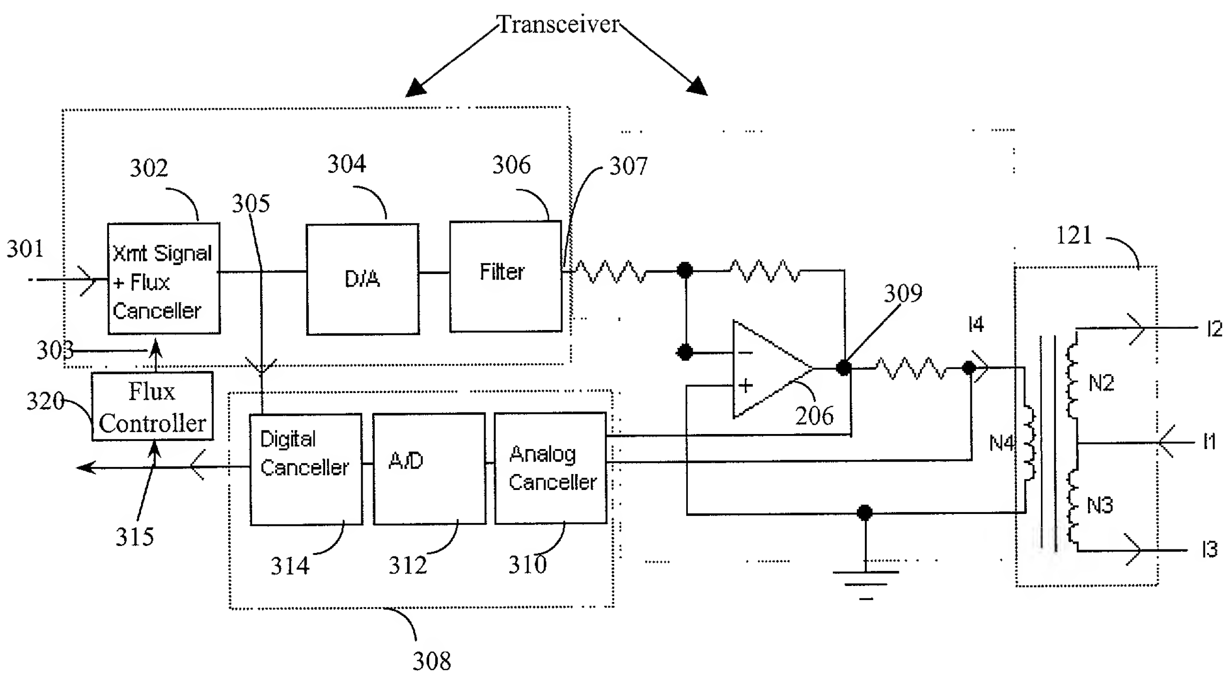


FIG. 4

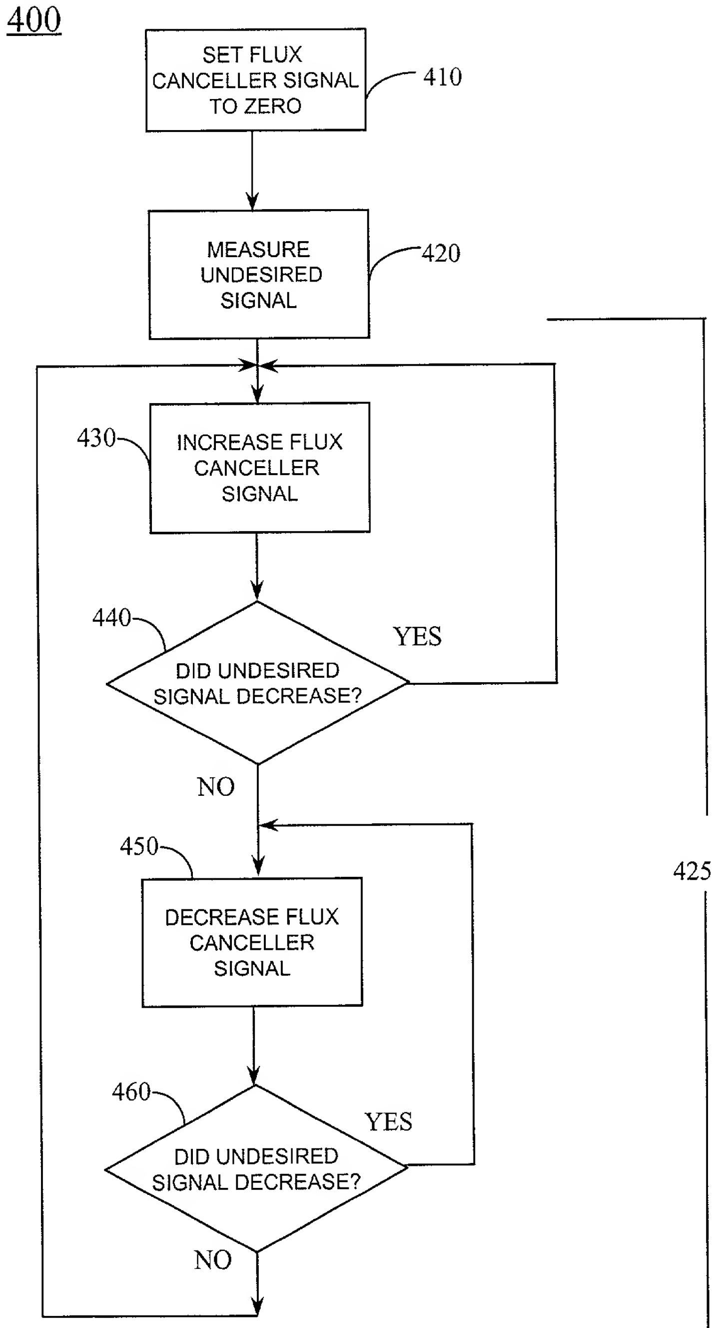

400
SET FLUX CANCELLER SIGNAL TO ZERO
410
MEASURE UNDESIRED SIGNAL
420
425
430
INCREASE FLUX CANCELLER SIGNAL
440
DID UNDESIRED SIGNAL DECREASE?
YES
NO
450
DECREASE FLUX CANCELLER SIGNAL
460
DID UNDESIRED SIGNAL DECREASE?
YES
NO

FIG. 5

Data Mode Arrangement

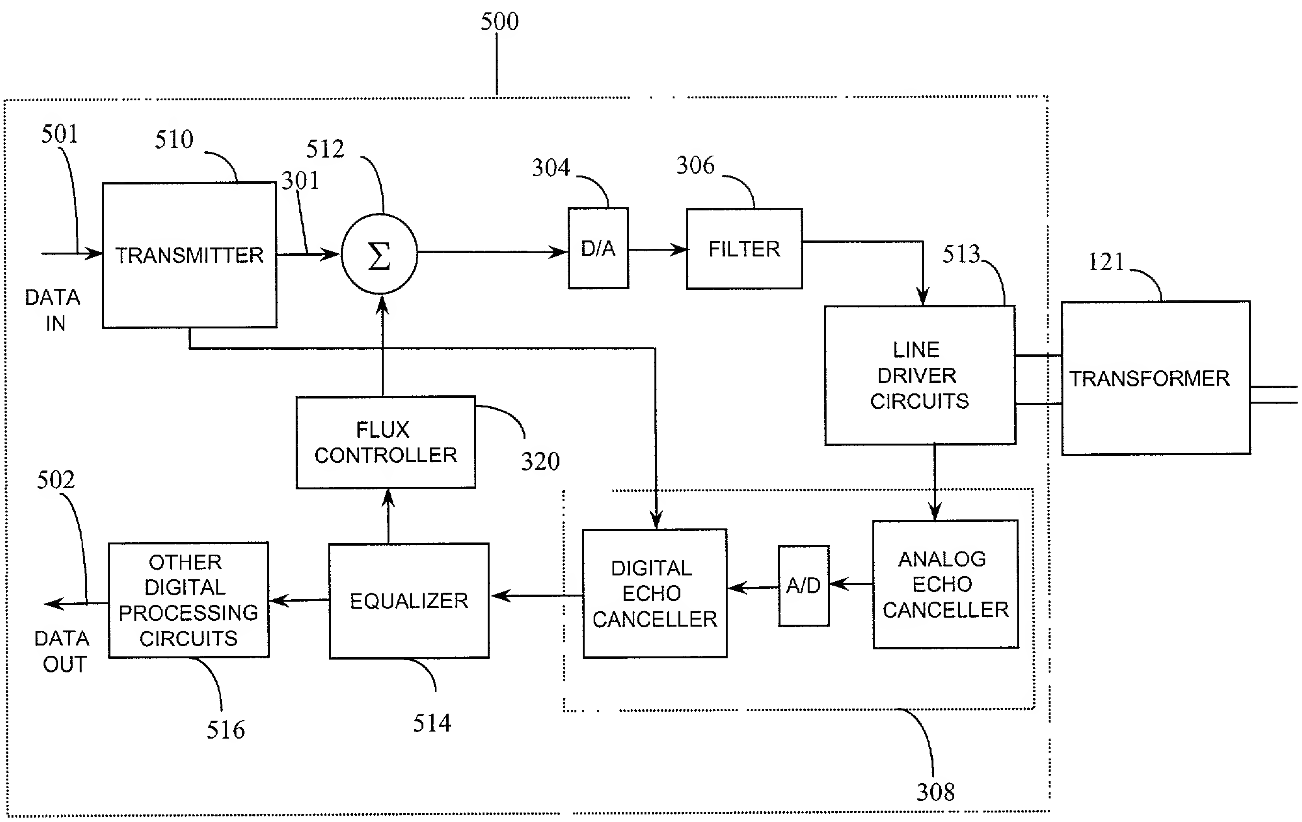


FIG. 6

Data Mode Algorithm

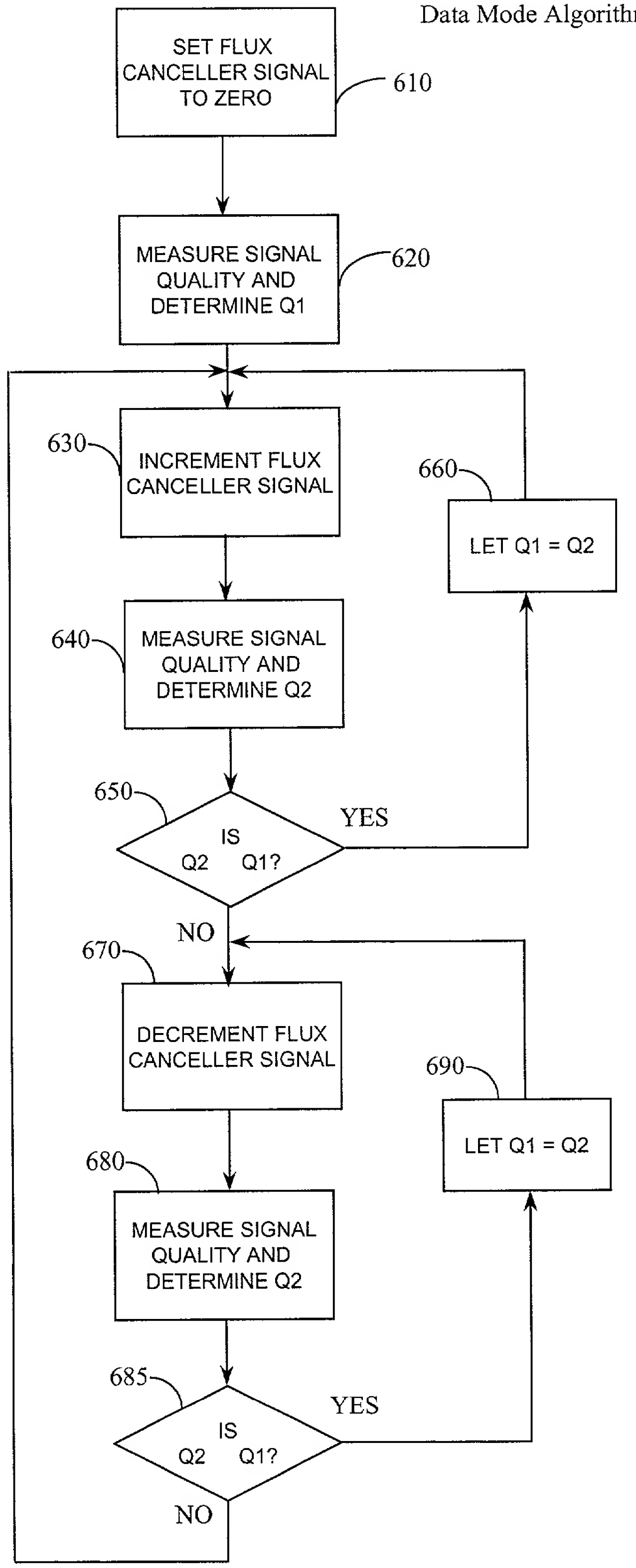
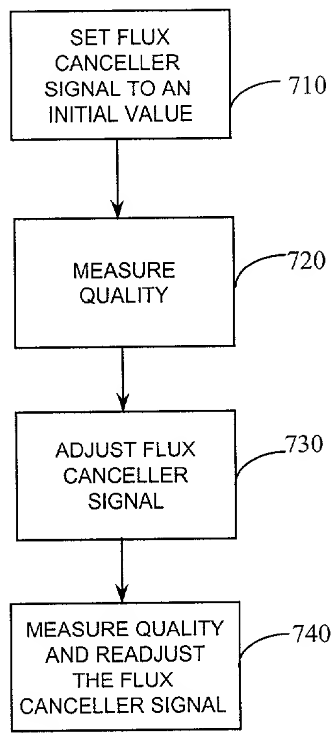


FIG. 7


SET FLUX CANCELLER SIGNAL TO AN INITIAL VALUE
710
MEASURE QUALITY
720
ADJUST FLUX CANCELLER SIGNAL
730
MEASURE QUALITY AND READJUST THE FLUX CANCELLER SIGNAL
740